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# THER HYDROGRAPHIC INVESTIGATIONS

# IN

# THE BAY OF FUNDY

By **E. HORNE CRAIGIE** B.A., University of Toronto and
**W. H. CHASE**, B.A., Acadia University.

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OTTAWA
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PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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# VII

# FURTHER HYDROGRAPHIC INVESTIGATIONS IN THE BAY OF FUNDY.

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(*With 25 figures and 1 map.*)

During the summer of 1914 a hydrographic section of the Bay of Fundy was made, a report of which appeared in the *Contributions to Canadian Biology*, 1914-1915.[1] At the beginning of July, 1915, it was suggested that a considerable amount of dredging should be done with a view to working out the fauna of the Bay of Fundy, and the opportunity was taken to combine with this work a repetition of the hydrographic observations made in the previous year and to extend them over the greater part of the Bay. It was thus possible to collect sufficient data to give a general idea of the conditions existing in the water of this important and interesting region.

## OBSERVATIONS MADE AND APPARATUS EMPLOYED.

The work was carried out during two cruises in the month of July. The first of these enabled dredging to be carried on at twenty-four stations in St. Mary bay, Nova Scotia, and observations to be taken at stations I to IV in the Bay of Fundy—the stations which were established in 1914. The work of the second cruise comprised dredging at nine stations in the Annapolis basin and the establishment of two more cross-sections and a longitudinal section of the Bay of Fundy.

In St. Mary bay and the Annapolis basin, the stations in which were numbered consecutively in Arabic numerals, temperatures and water samples were taken at the surface and at the bottom at each dredging station, largely for the sake of the connection of these conditions with the fauna found. At all the Bay of Fundy stations, observations were made at the surface, at depths of 5 and 10 fathoms, and then at 10 fathom intervals to the bottom. In the table of data the records for the bottom have been put opposite the nearest depth in tens of fathoms. The exact depth of the observation may be seen at a glance from the record of "Depth" near the top of the column for each station. The hydrographic data obtained in St. Mary bay and the Annapolis basin are tabulated here chiefly in order that they may be accessible when required, though few deducations can be made from them at present. At the Bay of Fundy stations V to XV, dredge hauls were taken; and at these and the Annapolis basin stations, surface plankton samples were also obtained.

The apparatus employed was the same as that used in 1914, and has been described in the report of the work done in that year. The temperature of the air and of the surface water were taken by means of a delicate chemical thermometer, all other temperatures were determined by reversing thermometers. The temperatures at 5 and 10 fathoms at station III, and from 10 to 40 fathoms at station IV, were determined by a Negretti-Zambra thermometer,[2] all other temperatures below the surface by a Richter thermometer.[3] The water samples were obtained by means of a Pettersen-

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[1] Craigie, E. Horne. "A Hydrographic Section of the Bay of Fundy in 1914."

[2] Magnaghi pattern frame, Negretti and Zambra thermometer No. 170664.

[3] Laboratoire Hydrographique, Kobenhavn, Preisliste. 1914, No. 75, thermometer No. 164.

Nansen water-bottle. A full description of both this water-bottle and the reversing thermometers may be found in the section on hydrographic work in the report on the "Investigation of the Bays of the Southern Coast of New Brunswick with a view to Their Use for Oyster Culture."[1]

The temperatures read on the Richter thermometer were all corrected for the expansion of the mercury column at the temperature at which the reading was made, and the corrected figures were recorded in the tables and used in constructing the temperature curves. All temperatures are in the centigrade scale.

The densities and salinities of the water samples were determined by W. H. Chase, but as he was called away by military duties, he was unfortunately prevented from completing the work.[2] Such discrepancies between density and salinity in many cases were found in the records that it was considered necessary to repeat the analysis of the samples, and Professor Vachon of Laval University was so kind as to do this during the summer of 1916. Unfortunately, Prof. Vachon found that the water samples must have altered by evaporation since they were collected, and it has accordingly been regretfully decided not to publish the data for the Bay of Fundy stations, but to confine this report to the temperature observations. The densities, salinities and chlorine contents of the samples from St. Mary bay, as determined by W. H. Chase, will be found in table III at the end of the report.

## LOCATION OF OBSERVATION STATIONS.

The positions of all the stations are indicated on the accompanying map, on which the fifty and hundred fathom lines have also been inserted, giving an idea of the conformation of the bottom of the Bay. The stations were located so as to give as complete sections as possible, showing the conditions existing in the various parts of the water. In making the observations, the stations were found by the use of a log.

Stations I to IV are on a straight line drawn from East Quoddy Head, Campobello island, to Boar's Head, Petit Passage, Long island, as follows:—

| | | | |
|---|---|---|---|
| Station | I | 7 | miles from East Quoddy Head. |
| " | II | 19 | " " " " |
| " | III | 27 | " " " " |
| " | IV | 37 | " " " " |

The remaining Bay of Fundy stations are located as follows:—

| | | | | |
|---|---|---|---|---|
| Station | V | 22 | miles | N.W. from Digby Gut. |
| " | VI | 8 | " | S. from Partridge Island, St. John Harbour. |
| " | VII | 14½ | " | S. from Partridge Island, St. John Harbour. |
| " | VIII | 21½ | " | S. from Partridge Island, St. John Harbour. |
| " | IX | 28 | " | S. from Partridge Island, St. John Harbour. |
| " | X | 11½ | " | E. from Station VII. |
| " | XI | 5 | " | S. from Quaco Head. |
| " | XII | 10½ | " | " " |
| " | XIII | 15½ | " | " " |
| " | XIV | 20½ | " | " " |
| " | XV | 16 | " | S.E. by S. from Quaco Head. |

The distances are measured in geographical miles.

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[1] Mavor, Craigie, and Detweiler in "Contributions to Canadian Biology, 1914-15."

[2] The responsibility for the planning of the work, selecting the stations, etc., rests with E. Horne Craigie, as does also the recording and working up of the temperature data, while observations on density and salinity were in charge of W. H. Chase. The two workers collaborated on the draft of the earlier part of this report, and on the preparation of the accompanying map and some of the figures. Owing to Mr. Chase's departure for the front, it has been necessary to complete the report without his assistance or criticism.

## DEDUCTIONS FROM DATA OBTAINED IN THE BAY OF FUNDY.

### *A.—Temperature Curves.*

From the corrected data obtained at each station, a temperature curve has been drawn (figs. 1-15), and upon the basis of these curves four profiles have been constructed representing respectively the three transverse sections and one longitudinal section of the Bay of Fundy. The discrepancies in depth at some stations shown by the curves and profiles are to be explained by the state of the tide when the observations were made. The bottom conformation has been drawn as accurately as possible with the aid of charts.

If the data for stations I to IV be compared with those recorded in August, 1914,[1] it will be observed that, with the exception of the surface temperatures at stations II and IV, all the readings are considerably lower in the new observations, the bottom temperatures averaging 2.7° lower than in 1914. The range of temperatures between the surface and the bottom is thus much greater in 1915, the difference in the surface temperatures being comparatively little. These differences between the temperatures found in the two years are to be explained, no doubt, by the fact that the new observations were taken six weeks earlier in the season than the old ones, when the heating effect of the summer sun and air had had less time to penetrate to the deeper water. Thus there is to be seen a very rapid fall of temperature in the layers of water near the surface (figs. 1-4). In this connection, it must be remembered that the heat conductivity of sea water is so slight as to be practically negligible. "The heat conveyed by the sun to the uppermost water-layers cannot therefore be propagated into deep water by conduction, but only through movements of the water-waves, currents, convection 'currents,' etc."[2] The fact that the deeper water is heated so much in a period of six weeks must be attributed to the vertical mixing of the water by the great tides occurring in this region.

Another effect of this vertical mixing by the strong tidal currents was referred to in the previous report, namely, the considerable areas of the same, or nearly the same temperature occurring at many of the stations. This is most marked in the case of the stations farther up the Bay, the temperatures at stations X to XV (figs. 10-15) inclusive being practically constant between a depth of 5 fathoms and the bottom. The fact that this uniformity becomes more marked in the upper part of the Bay bears out the theory that the tides are responsible for it, the tides being greatest at the head of the Bay, while the water there is shallower, so that the tides are likely to effect a more complete mixing of the mass of water.

Helland-Hansen, generalizing upon the basis of temperature curves for four stations distributed over the Atlantic from the Faroe-Shetland channel to the Sargasso Sea says: "From the surface downwards the temperature falls very rapidly for the first hundred metres; at 100 metres it is 4° to 6° colder than at the surface. Beyond 100 metres the temperature decreases at first much more slowly. . . . The layers in which the temperature changes very rapidly are called 'discontinuity layers' (by the Americans 'thermocline,' and by the Germans 'Sprungschicht')."[3] The curves obtained for the first four Bay of Fundy stations, i.e. those nearest the open Atlantic, (figs. 1-4) agree with these observations to an extent which seems little short of remarkable in shallow and enclosed water, especially where conditions are so peculiar as they are in the Bay of Fundy. Indeed it would hardly seem justifiable to consider the correspondence as more than a matter of chance were it not for the fact that it appears even more clearly in the curves for the same stations in August, 1914. The comparison is made particularly apt by the fact that Helland-Hansen's observations were made between June 24 and August 10—at practically the same time of year as our own work.

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[1] Craigie, E. Horne. "A Hydrographic Section of the Bay of Fundy in 1914." Contributions to Canadian Biology. 1914-1915.

[2] Helland-Hansen in "The Depths of the Ocean," by Sir John Murray and Dr. Johan Hjort, p. 226.

[3] "The Depths of the Ocean," p. 223.

While the density and salinity records are not being included in this report, for the reasons explained above, it is perhaps worth while remarking in this connection that the observed densities also correspond rather closely with the records obtained in the part of the open Atlantic near Nova Scotia by the *Challenger* expedition in May 1873. The surface densities for the *Challenger* stations 49 and 50 are, respectively, 1.02354 and 1.02451, the bottom readings for the same stations being 1.02400 and 1.02546. The depth at station 40 was only 85 fathoms, that at station 50 was 1,250 fathoms.[1]

The surface and bottom densities found at our stations I to IV were:—

| Station— | I. | II. | III. | IV. |
|---|---|---|---|---|
| Surface.. .. .. .. .. .. .. .. .. .. .. .. | 10242 | 10240 | 10239 | 10246 |
| Bottom.. .. .. .. .. .. .. .. .. .. .. .. | 10246 | 10250 | 10252 | 10252 |

The surface densities throughout the Bay varied from 10238 (stations VI and VII) to 10248 (station XIII). The bottom densities ran from 10244 (station X) to 10252 (stations III and IV). Thus it appears that the density of the waters of the Bay of Fundy corresponds quite closely with that of the neighbouring part of the Atlantic. Once more, no doubt, the thorough mixture brought about by the tides is to be held responsible for this, as it seems improbable that evaporation in the Bay of Fundy is nearly sufficient to counterbalance the influx of fresh water.

Helland-Hansen remarks that the high surface temperature shown by his curves "is principally due to the absorption of heat rays from the sun. In places the water is heated by contact with warm air, but this source of heat is of less importance, *the temperature of the surface water being, as a rule, higher than the temperature of the air*."[2] He makes no mention of the time of day at which his readings were made, which, of course, would greatly affect the air temperature—unless he refers to the mean air temperature of the day. All our observations, practically, were made in daylight, and in no case was the air less than 2.2° warmer than the surface water, while in most cases it was considerably more. It may be noted in passing that although three of Helland-Hansen's four stations mentioned above are farther north than the Bay of Fundy, and all four are in the open Atlantic, his lowest surface temperature (that in the Faroe-Shetland channel) is 13°C.—more than 1° higher than the highest reading obtained in the Bay of Fundy. In looking over the records of the *Challenger* observations[3] in July, 1873, it is found that at 6 a.m. on the 16th of the month the air temperature was as much as 3°F. below that of the surface water in the harbour of Madeira; but in the majority of cases the air was warmer than the surface water. On the 15th the mean air temperature was 0.1° F. less than the mean surface water temperature, and on the 26th it was 0.5° F. less, but such cases are considerably in the minority. In May, 1873, when the *Challenger* was in this part of the Atlantic, only in a few cases again did the water temperature exceed the air temperature; and in no case was the mean surface water temperature for the day higher than the mean air temperature, until the 22nd of the month, when the ship had gone south to about the 40th parallel of north latitude.

The temperature curves for stations I to IV do not show so clearly as did those of 1914 the resemblance between stations II, III, and IV, and the distinct difference from these of station I. The curve for station I shows a peculiar rise in temperature between 40 and 70 fathoms. A similar, though smaller rise occurs at the same depth in station II and is represented in station III also, at a somewhat deeper point. This is evidently the effect of some current and its occurrence both in the Grand Manan Channel (station I) and at the two neighbouring stations in the open Bay would seem to suggest that it is tidal. It is to be regretted that there was not an opportunity to make further observations with a view to elucidating this matter.

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[1] Report on the Specific Gravity of Ocean Water, observed on board H.M.S. *Challenger* during the years 1873-76." By J. Y. Buchanan, pp. 14 and 16. Report on the Scientific Results of the Voyage of H.M.S. *Challenger*, Phys. and Chem., Vol. I.

[2] "The Depths of the Ocean," p. 225. (The italics are due to the present writer.)

[3] "Meteorological Observations made during the voyage of H.M.S. *Challenger*, 1873-76." Report on the Scientific Results of the Voyage of H.M.S. *Challenger*, Narrative, Vol. II, 1882.

It may be noted that in 1914 a similar, though smaller rise in temperature occurred at a depth of 60 fathoms at station II with the tide two-thirds flood, while in the present case it was one-half flood at the same station. At station I, where the irregularity is most marked, the tide was flood, while at the same station in 1914 no such irregularity was found with the tide one-third flood. Thus from the present limited data there is no indication that this condition occurs regularly at any particular state of the tide. A similar rise is to be seen at a depth of 20 fathoms at station IX (fig. 9).

### *B. Profiles.*

The profile for the section from East Quoddy Head to Petite Passage (fig. 16) shows no marked disagreement with that obtained in 1914. The cold water along the slope from Grand Manan found in 1914 does not appear in the new section. As before, the temperatures tend to be a little higher on the Nova Scotia side of the bay than on the New Brunswick side.[1] The irregularities showing in the graphs, which were discussed in the previous section are not represented in the profile.

The water below 6°C. occupying most of this profile does not appear in that of the St. John to Digby section (fig. 17), and a similar position but less space is occupied by the water between 6.38° and 7°. The tendency of the water towards the Nova Scotia side to be warmer does not appear in this section.

The profile from Quaco Head to Port Lorne (fig 18), shows that the water below 7° has disappeared, and its place, though much less space, is taken by water between 7.9° and 8°. From these three profiles it is easy to picture each successive layer of cold water running up the bay and gradually diminishing in extent until it finally disappears, its place being taken by the next layer. Of course, these remarks are not to be taken as meaning that the water is believed to be actually divided into distinct layers behaving thus.

The longitudinal section from Cape Chignecto to station III (fig. 19) shows that the layers do not simply taper and fade away, but end rather suddenly, clearly suggesting that the water flows up the bay and the lower layers are continually retarded by friction with the bottom, though this appearance is probably due to tidal action. A peculiar condition appears between stations VII, X, and XII. The presence of warmer water at station VII might be attributed to warm water coming in from the Atlantic surface, passing along the south shore, and turning north about this region (see fig. 20), but the source of the cold water at station X is not so clear. It seems possible that as the warm surface water is turned north across the bay (fig. 20) the cold water below goes on up the bay and so comes to the surface. It is most unfortunate that there was not time to make a complete transverse section through station X. Presumably the condition will be due to tidal action, but just how it is produced is not evident in the present state of our knowledge.

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[1] I am informed by Dr. A. G. Huntsman that observations taken during the summer of 1916, nearer the shore on each side, showed this much more markedly, so that the isotherms should really dip quite rapidly near the coast in this profile. His observations appear to indicate a current entering at the mouth of the bay and passing up the Nova Scotia side, producing a corresponding current in an outward direction on the New Brunswick side. A somewhat similar condition, with peculiar tidal changes, was demonstrated in the St. Croix River by Craigie in 1914. (Craigie, E. Horne. "Hydrographic Investigations in the St. Croix River and Passamaquoddy Bay in 1914." Contributions to Canadian Biology, 1914-1915.)

### *C. Horizontal Distribution of Temperature.*

In the hope that more light might thereby be thrown on the subject, three maps have been constructed, showing the distribution of temperature in the surface water (fig. 20) and at depths of ten fathoms and thirty fathoms respectively (figs. 21 and 22). As pointed out above, figure 20 shows an indication of an influx of warm surface water, which passes along the south shore and then turns across the bay (see foot note on page 131). If this represents a current in this direction, however, the deeper water should be colder than on the other side, as it must come in from the cold Labrador current, and we have already seen that the results both seasons tend rather the other way. Figures 21 and 22 show no sign of such a circulation, but rather combine with the four profiles to indicate a simple tongue of cold water up the middle of the bay. The cold area on the slope of Grand Manan in the 1914 profile especially supports this. There is nothing at ten fathoms corresponding in any way to the area of colder water appearing at the surface of station X (8·46° surface temperature) and points east of it, nor does the conformation of the shore appear to suggest any satisfactory explanation. That proposed at the end of the previous section appears to be the only one at present. The isolated area of warmer water east of Grand Manan (station II) in fig. 20 does not seem to be explicable on the basis of the present data either. The probable position of the 10°C. isotherm along the north shore is indicated by a broken line, although, of course, there are not sufficient data to locate this properly.

### DEDUCTIONS FROM DATA OBTAINED IN ST. MARY BAY.

From the data obtained in St. Mary bay (table II) a plan of the distribution of temperature in the surface water of that bay has been drawn (fig. 23). It shows a rather uniform arrangement with gradually increasing temperature as one passes up the bay from Petit Passage, the shape of the isotherms suggesting that there may be a current up each side with a reverse current down the middle. Immediately below Petit Passage the effects of the tremendous tidal currents through that channel are visible, producing a rather complicated arrangement of the isotherms, due apparently to several interfering cross-currents. The arrangements of the water must, of course, vary very greatly at different states of the tide and the fact that all the observations must be taken at different times makes it improbable that the diagram represents such a condition as ever exists at any one time.

It has been thought worth while also to include a diagram representing a longitudinal section of St. Mary bay (fig. 24), although it must be fully recognized that such a profile, constructed from temperature data taken at the surface and the bottom only, is of a very tentative nature. The figure shows gradual and apparently rather uniform rise of temperature as one passes up the bay, just such as might be expected, the colder area at the surface of station 15 being the only indication of the cross-currents suggested by the surface diagram (fig. 23). No doubt if temperatures at intermediate depths had been taken, more might have been seen. The relations of the cold water appearing at the bottom of stations 13 and 15 are shown by fig. 25, which represents a line carried down the bay from station 13 somewhat farther west than the line in fig. 24. It is seen that this cooler water is spread out sideways from a layer which probably approaches the surface about the mouth of the bay, and occupies almost the whole depth at station 22. It will be noted that, the bay being rather shallow throughout, the temperatures are all comparatively high.

The bottom temperatures in the Annapolis basin (stations 26-33, table II) are peculiar in being much lower in many cases (especially station 31) than any water entering from the river (station 33) or any present in Digby Gut (station 25).

### SUMMARY.

This set of observations is a continuation and extension of that made in 1914. The stations have been selected in such a way as to form three transverse sections and one longitudinal section of the bay of Fundy, thus making it possible to get a fairly clear idea of the temperature distribution in this interesting body of water by examining the profiles constructed and the accompanying diagrams showing the horizontal distribution of temperature at the shallower-levels.

The observations made at the stations where work was carried on in 1914 show little difference in surface temperature, but markedly colder water below. The fact that a seasonal difference of only six weeks makes such a great difference in the temperature of the deep water shows how great is the effect of vertical mixing due to the very great tides. This effect is also seen in the large areas of very uniform temperature found in both years.

The results obtained at stations near the mouth of the bay show an interesting agreement with observations made by Helland-Hansen in the open Atlantic. The statement of this investigator that the temperature of the surface water is, as a rule, higher than the air temperature is not borne out by the Bay of Fundy observations, nor by those of the *Challenger* expedition in this region of the Atlantic.

A slight rise of temperature at an intermediate depth, seen in three stations near the mouth of the bay, gives evidence of deep currents, but no data are available from which definite information concerning these can be obtained.

There is a clear indication that the water on the Nova Scotia side of the lower part of the bay is, on the whole, warmer than on the New Brunswick side, and the plan of the surface temperatures suggests a current of warm surface water from the Atlantic flowing in along the south shore and then turning north about half way up the bay, so that its influence is not visible in the higher profiles. All the other evidence, however, indicates a simple tongue of cold water up the middle of the bay.

Several points with regard to the surface temperatures remain unexplained.

The plan of distribution of temperature in the surface water of St. Mary bay shows a rather uniform increase of temperature in the upper part of the bay, with indications of certain currents and tidal disturbances. The longitudinal profile, which is based upon insufficient data, gives no suggestion of any peculiar or striking conditions.

In conclusion, it remains only to express our indebtedness to Dr. Philip Cox, who accompanied us on both cruises, and Mr. J. R. McMurrich, who joined the party on the second, as well as to Dr. A. B. Macallum, Dr. C. C. Benson, and Dr. A. G. Huntsman for valuable assistance and criticism. We are also deeply indebted to Professor Vachon, Laval University, for the trouble he took in re-titrating the water samples.

## TABLE I—Temperature Records for Bay of Fundy Stations in 1915.

| Station. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | XIII. | XIV. | XV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | July 14 | July 14 | July 13 | July 13 | July 31 | July 23 | July 22 | July 22 | July 23 | July 28 | July 28 | July 28 | July 27 | July 27 | July 29 |
| Time | 12.30 P.M.–1.30 P.M. | 9.45 A.M.–11.00 A.M. | 6.00 P.M.–8.00 P.M. | 3.45 P.M.–4.40 P.M. | 10.25 A.M.–11 30 A.M. | 9.00 A.M.–10.30 A.M. | 11.15 A.M–12.30 P.M. | 1.30 P.M.–3.00 P.M. | 4.00 P.M.–5.15 P.M. | 8.30 A.M.–9.15 A.M. | 11.20 A.M.–12.15 P.M. | 10.00 A.M.–11.00 A.M. | 10.00 A.M.–11.30 A.M. | 8.25 A.M.–9.30 A.M. | 12.15 P.M.–1.10 P.M. |
| Bottom | Sand. | Mud. | Mud. | Sand & hard. | Gravel. | Shells. | Coarse gravel. | Shells. | Rock. | Coarse gravel. | Sand. | Rock. | Sand & hard. | Rock. | Sand. |
| Depth | 81 F. | 64 F. | 114 F. | 83 F. | 55 F. | 43 F. | 55 F. | 48 F. | 47 F. | 47 F. | 30·5 F. | 36 F. | 41 F. | 35 F. | 34 F. |
| Tide | Flood. | ½ Flood. | Ebb. | ¾ Ebb. | ½ Flood. | ¼ Ebb. | ¾ Ebb. | ¼ Flood. | ½ Flood. | ½ Flood. | ⅜ Flood. | ¼ Flood. | ⅜ Flood. | ½ Flood. | ⅜ Flood. |
| Air Temperature | 16·10° | 13·90° | 14·25° | 16·20° | 13·70° | 14·66° | 17·95° | 15·75° | 14·75° | 12·93° | 14·73° | 14·76° | 11·92° | 15·39° | 12·34° |
| Temperature at Surface | 9·86° | 11·69° | 10·61° | 11·38° | 10·41° | 10·10° | 12·33° | 12·68° | 11·71° | 8·46° | 10·51° | 9·20° | 8·45° | 9·56° | 10·10° |
| " " 5 F | 8·07° | 7·49° | 9·7° | 9·5° | 7·79° | 9·27° | 10·15° | 11·13° | 8·33° | 7·89° | 8·96° | 8·04° | 8·41° | 8·93° | 9·54° |
| " " 10 F | 7·55° | 7·47° | 6·2° | 8·3° | 7·15° | 7·96° | 7·88° | 7·17° | 7·82° | 7·90° | 8·74° | 8·03° | 8·40° | 8·91° | 9·54° |
| " " 20 F | 7·15° | 6·00° | 6·12° | 7·7° | 6·80° | 7·39° | 6·70° | 7·11° | 7·95° | 7·84° | 8·41° | 7·99° | 8·43° | 8·91° | 9·54° |
| " " 30 F | 5·74° | 6·00° | 5·59° | 7·1° | 6·77° | 7·30° | 6·51° | 6·80° | 7·27° | 7·82° | 8·41° | 7·97° | 8·43° | 8·93° | 9·54° |
| " " 40 F | 5·73° | 5·64° | 5·59° | 6·2° | 6·70° | 7·03° | 6·42° | 6·79° | ...... | 7·82° | 8·44° | 7·95° | 8·42° | ...... | ...... |
| " " 50 F | 6·26° | 5·79° | 5·59° | 5·81° | 6·71° | ...... | 6·38° | 6·77° | 6·92° | 7·81° | ...... | ...... | ...... | ...... | ...... |
| " " 60 F | 6·08° | 5·63° | 5·59° | 5·78° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 70 F | 5·72° | ...... | ...... | 5·76° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 75 F | ...... | ...... | 5·70° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 80 F | 5·73° | ...... | ...... | 5·77° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 90 F | ...... | ...... | 5·64° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 100 F | ...... | ...... | 5·64° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| " " 114 F | ...... | ...... | 5·66° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |

TABLE II.—Tempratures in St. Mary Bay and Annopolis Basin in 1915. (°Centigrade.)

| Station. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | July 7 | July 7 | July 7 | July 7 | July 7 | July 7 | July 7 | July 8 | July 8 | July 7 | July 13 |
| Time | 11.15 A.M. | 10.30 A.M. | 12.10 P.M. | 1.45 P.M. | 8.45 A.M. | 2.45 P.M. | 3.30 P.M. | 8.10 A.M. | 8.50 A.M. | 4.35 P.M. | 1.35 P.M. |
| Bottom | Mud. | Mud. | Mud. | Gravel. | Mud. | Mud. | Shell & sand. | Sand. | Sand. | Sand. | Sand. |
| Depth | 4 F. | 7 F. | 14·5 F. | 15·5 F. | 11·5 F. | 11·5 F. | 9·5 F. | 18 F. | 18 F. | 2·5 F. | 17·5 F. |
| Tide | ¾ Ebb. | ¼ Ebb. | ⅔ Ebb. | Ebb. | ¼ Flood. | ¼ Flood | ½ Flood. | ¾ Ebb. | ¾ Ebb. | ½ Flood. | ¾ Ebb. |
| Air Temperature | ...... | ...... | ...... | 15·60° | ...... | 15·62° | 15·35° | 13·85° | 15·00° | 14·05° | 14·35° |
| Surface Temperature | 14·80° | 13·78° | 13·92° | 13·95° | 13·05° | 13·52° | 12·90° | 12·96° | 12·79° | 11·39° | 11·96° |
| Bottom Temperature | 13·40° | 11·82° | 11·61° | 11·37° | 10·54° | 10·30° | 10·22° | 9·08° | 8·68° | 10·77° | 9·29° |

| Station. | 12. | 13. | 14. | 15. | 16. | 17. | 18. | 19. | 20. | 21. | 22. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | July 8 | July 13 | July 8 | July 8 | July 8 | July 13 | July 13 | July 13 | July 13 | July 13 | July 13 |
| Time | 10.20 A.M. | 1.00 P.M. | 10.55 A.M. | 11.45 A.M. | 12.25 P.M. | 11.15 A.M. | 9.45 A.M. | 9.00 A.M. | 10.30 A.M. | 5.40 A.M. | 4.55 A.M. |
| Bottom | Rock. | Sand. | Rock. | Rock. | Rock. | Rock. | Coarse gravel. | Rock. | Sand. | Sand. | Rock. |
| Depth | 14·5 F. | 18 F. | 19·5 F. | 18·5 F. | 7·5 F. | 26 F. | 14·5 F. | 6·5 F. | 26 F. | 23·5 F. | 19·5 F. |
| Tide | ¼ Ebb. | ¼ Ebb. | ⅜ Ebb. | ⅝ Ebb. | Ebb. | ⅜ Flood | ⅜ Flood. | ⅜ Flood. | ⅔ Flood. | Ebb. | ¼ Flood. |
| Air Temperature | 15·58° | 19·38° | 15·90° | 15·65° | 13·43° | 15·67° | 13·57° | 13·30° | 13·54° | 12·36° | 11·37° |
| Surface Temperature | 12·80° | 11·45° | 9·57° | 10·12° | 10·96° | 10·48° | 11·43° | 11·67° | 10·09° | 9·29° | 9·63° |
| Bottom Temperature | 8·29° | 8·79° | 7·81° | 8·44° | 10·07° | 8·69° | 9·39° | 10·90° | 8·34° | 8·06° | 8·09° |

| Station. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. | 33. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | July 13 | July 13 | July 23 | July 23 | July 23 | July 24 | July 23 | July 23 | July 24 | July 24 | July 24 |
| Time | 7.40 A.M. | 8·15 A.M. | 2.30 P.m. | 10.15 A.M. | 3.30 P.M. | 9.05 A.M. | 11.15 A.M. | Noon. | 10.00 A.M. | 10.30 A.M. | 11.30 A.M. |
| Bottom | Gravel. | Rock. | Rock. | Mud. | Mud. | Mud & shell. | Mud. | Mud. | Mud. | Sand. | Gravel. |
| Depth | 15·5 F. | 8·5 F. | 38 F. | 6 F. | 11·5 F. | 7 F. | 3·5 F. | 2·5 F. | 7·5 F. | 8 F. | 9 F. |
| Tide | ½ Flood. | ¼ Flood. | Ebb. | ¼ Ebb. | ¼ Fbb. | Flood. | ¼ Ebb. | ⅜ Ebb. | ¼ Ebb. | ¼ Ebb. | ¼ Ebb. |
| Air Temp | 13·96° | 13·09° | 16·85° | 15·57° | 18·50° | 16·32° | 17·25° | 17·96° | 14·63° | 17·76° | 18·55° |
| Surface Temperature | 10·22° | 10·93° | 11·66° | 11·14° | 11·92° | 9·41° | 12·70° | 12·58° | 11·22° | 13·31° | 15·39° |
| Bottom Temperature | 9·17° | 10·29° | 9·30° | 9·06° | 8·76° | 8·54° | 10·04° | 11·04° | 6·99° | 12·19° | 13·39° |
| 15 Fathom Temperature | ...... | ...... | 9·80° | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |

TABLE III.—Specific Gravity, Chlorine Content, and Salinity of Water Samples from Bottom of St. Mary Bay Stations in 1915.

| Station. | Sp. Gt. at 15·56° C. | % Chlorine. | % Total Salts. | Station. | Sp. Gt. at 15·56° C. | % Chlorine. | % Total Salts. |
|---|---|---|---|---|---|---|---|
| 1 | 10243 | 1·817 | 3·276 | 13 | 10248 | 1·832 | 3·304 |
| 2 | .......... | (1·819) | (3·280) | 14 | 10249 | 1·842 | 3·322 |
| 3 | 10248 | 1·825 | 3·291 | 15 | 10249 | 1·849 | 3·334 |
| 4 | 10247 | 1·833 | 3·306 | 16 | 10247 | 1·840 | 3·318 |
| 5 | 10247 | 1·832 | 3·304 | 17 | 10248 | 1·845 | 3·327 |
| 6 | 10248 | 1·835 | 3·309 | 18 | 10245 | 1·835 | 3·309 |
| 7 | 10248 | 1·835 | 3·309 | 19 | 10247 | 1·855 | 3·346 |
| 8 | 10247 | 1·831 | 3·302 | 20 | 10247 | 1·869 | 3·370 |
| 9 | 10248 | 1·842 | 3·322 | 21 | 10246 | 1·866 | 3·365 |
| 10 | 10248 | 1·842 | 3·322 | 22 | 10245 | 1·861 | 3·354 |
| 11 | 10246 | 1·841 | 3·319 | 23 | 10249 | 1·857 | 3·347 |
| 12 | 10249 | 1·836 | 3·311 | 24 | 10248 | 1·861 | 3·353 |

The density of each water sample was determined at room temperature by means of a delicate hydrometer, and corrected to read at 15.56° C. by Buchanan's Diagram.[1] The methods of analysis and of calculating the salinity were those of Dittmar.[1]

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[1] Report on the Scientific Results of the Voyage of H.M.S. *Challenger*. Physics and Chemistry, Vol. I, 1884.

J. Y. Buchanan. "Report on the Specific Gravity of Samples of Ocean Water observed on board H.M.S. *Challenger*, during the years 1873-76." Diagram 1.

William Dittmar. "Report on Researches into the Composition of Ocean Water collected by H.M.S. *Challenger* during the years 1873-76." pp. 4 and 40.

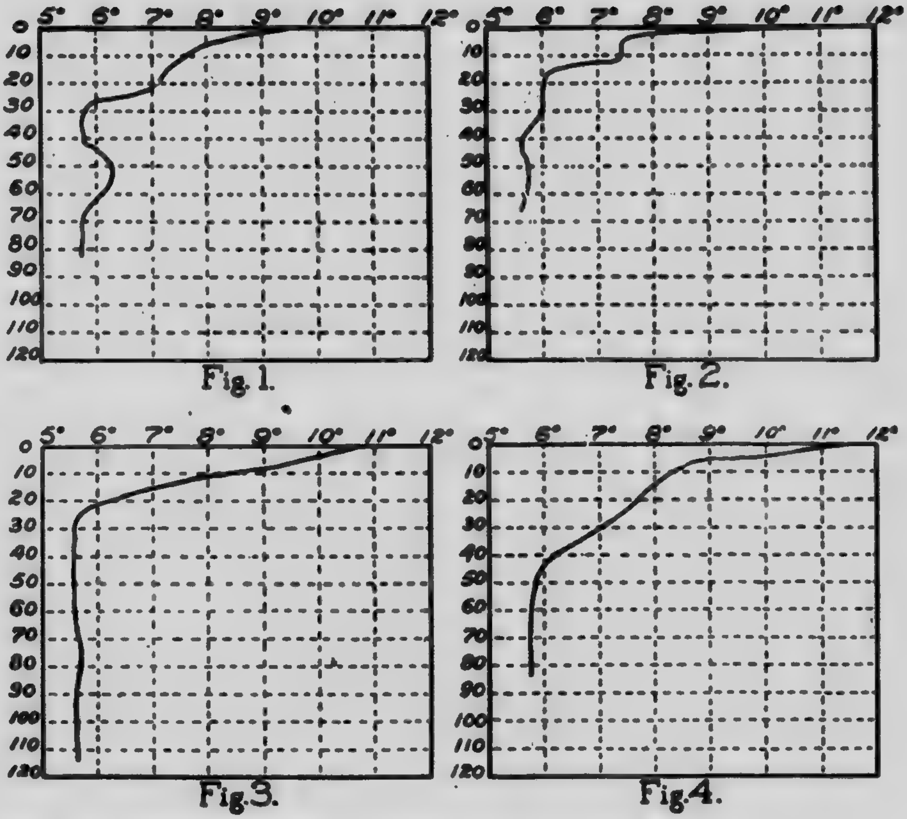


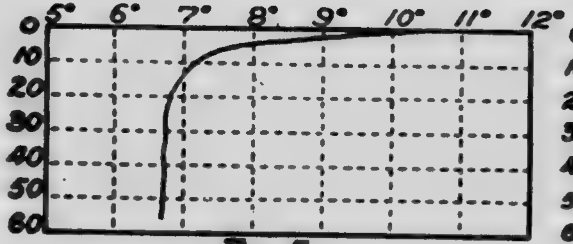
Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Figs. 1–4. Temperature curves for stations I. to IV. respectively.



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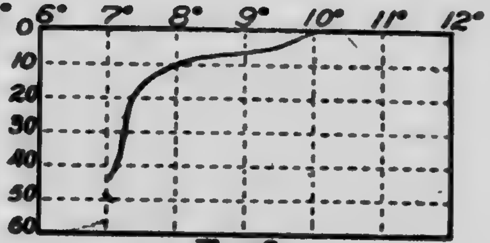

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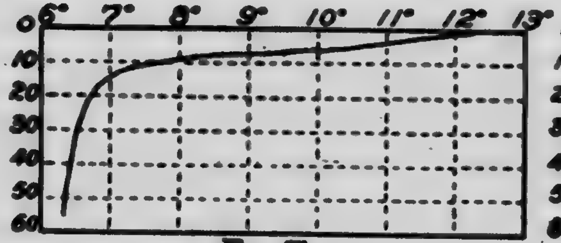

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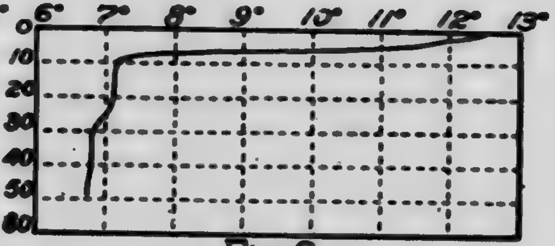

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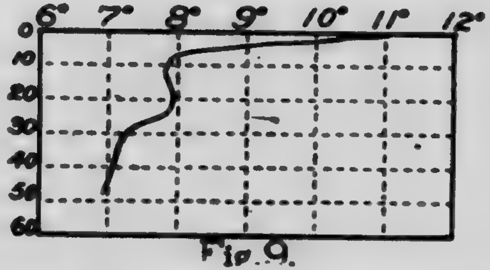

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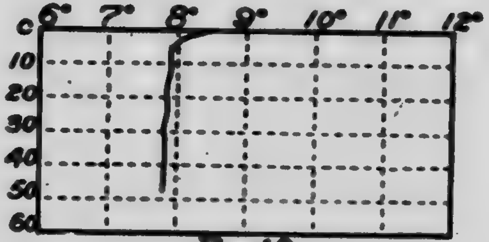


Fig. 10.

Figs. 5-10. Temperature curves for stations V. to X. respectively.

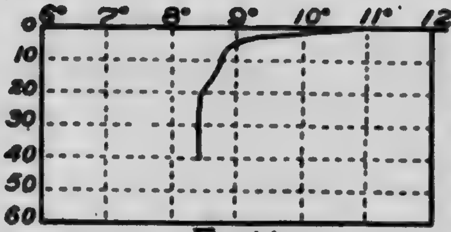
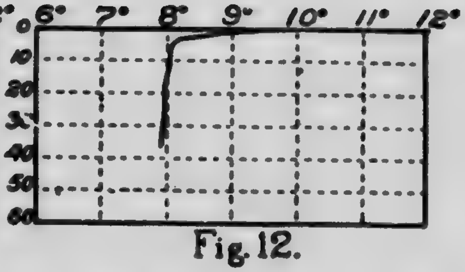


Fig. 11.



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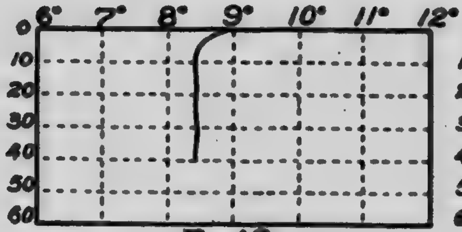
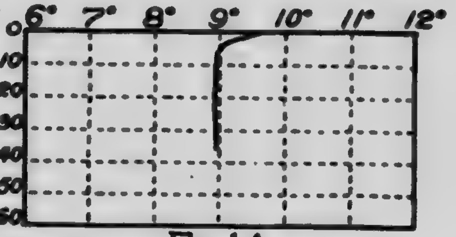


Fig. 13.



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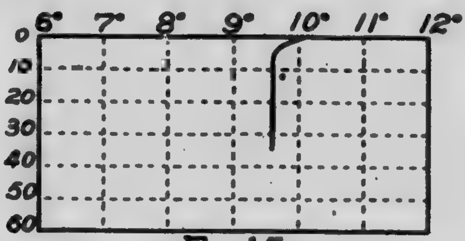


Fig. 15.

Figs. 11-15. Temperature curves for stations XI. to XV. respectively.

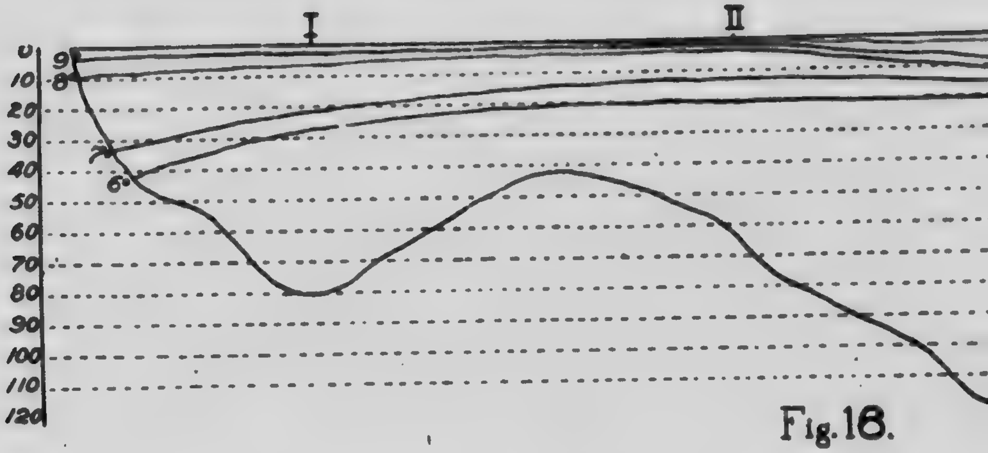
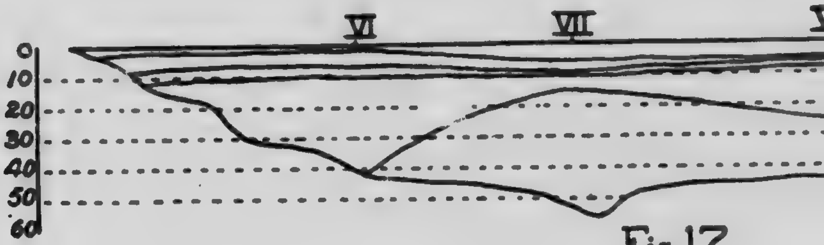


Fig. 16.



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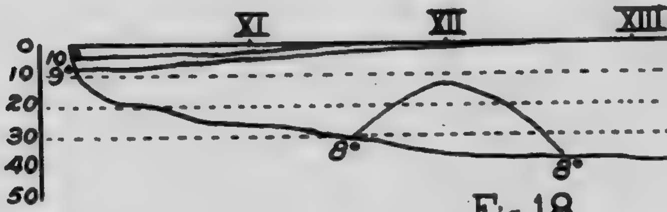

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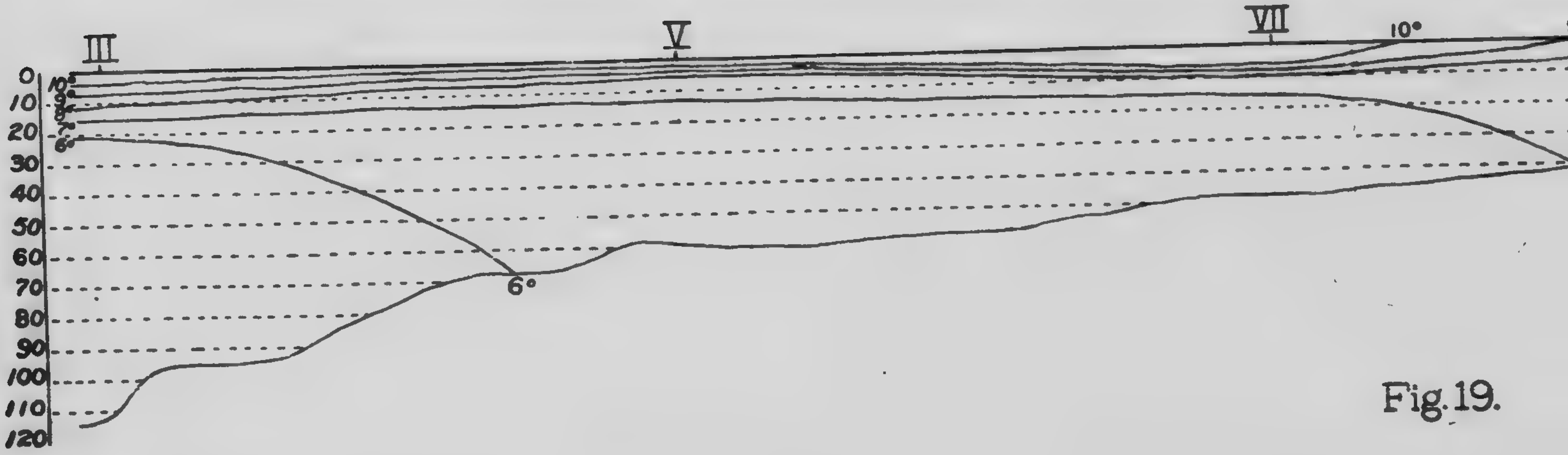

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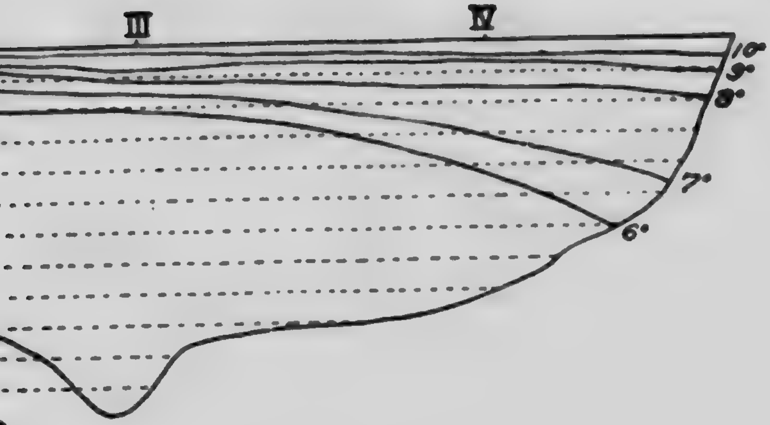

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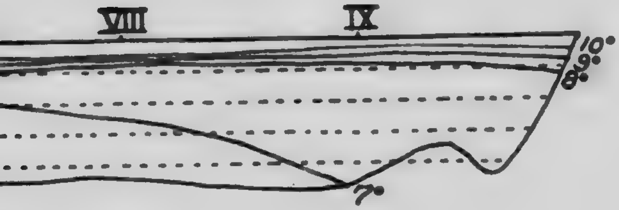

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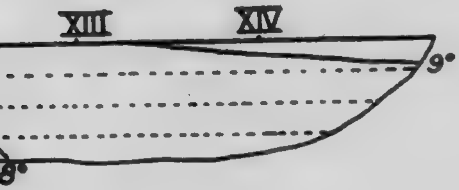

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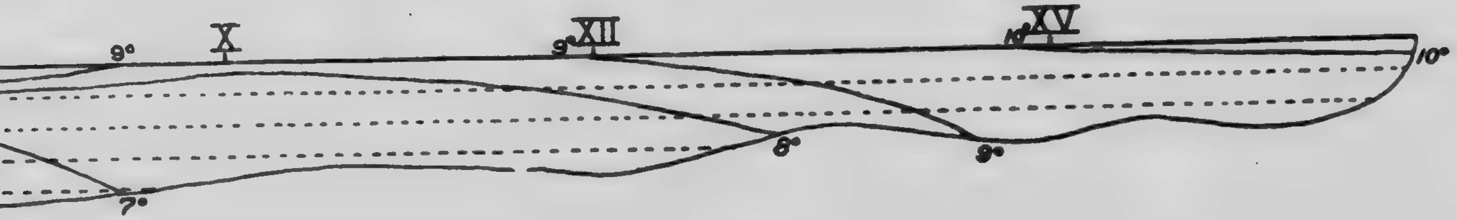


19.

Figs. 16. Isothermal profile for section of Bay of Fundy from East Quoddy Head to Petit Passage.
" 17. Isothermal profile for section of Bay of Fundy from St. John to Digby.
" 18. Isothermal profile for section of Bay of Fundy from Quaco Head to Port Lorne.
" 19. Isothermal profile for longitudinal section of Bay of Fundy from Cape Chignecto to station III.

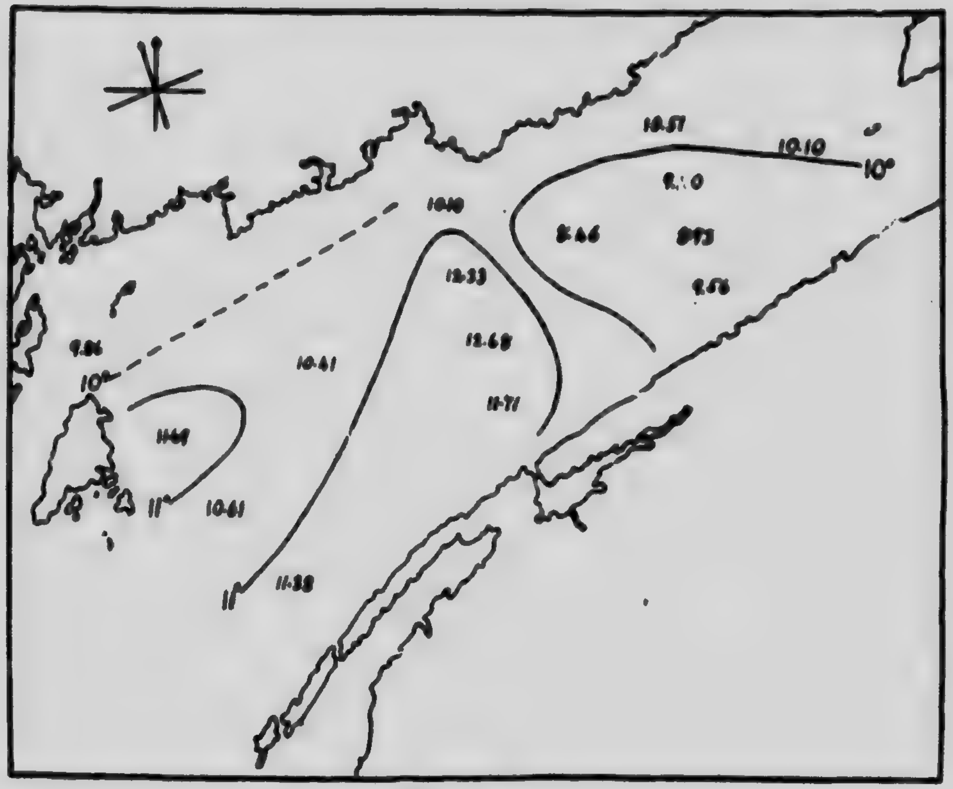


**Fig. 20.**

Figs. 20. The Bay of Fundy, showing temperatures of the surface water.

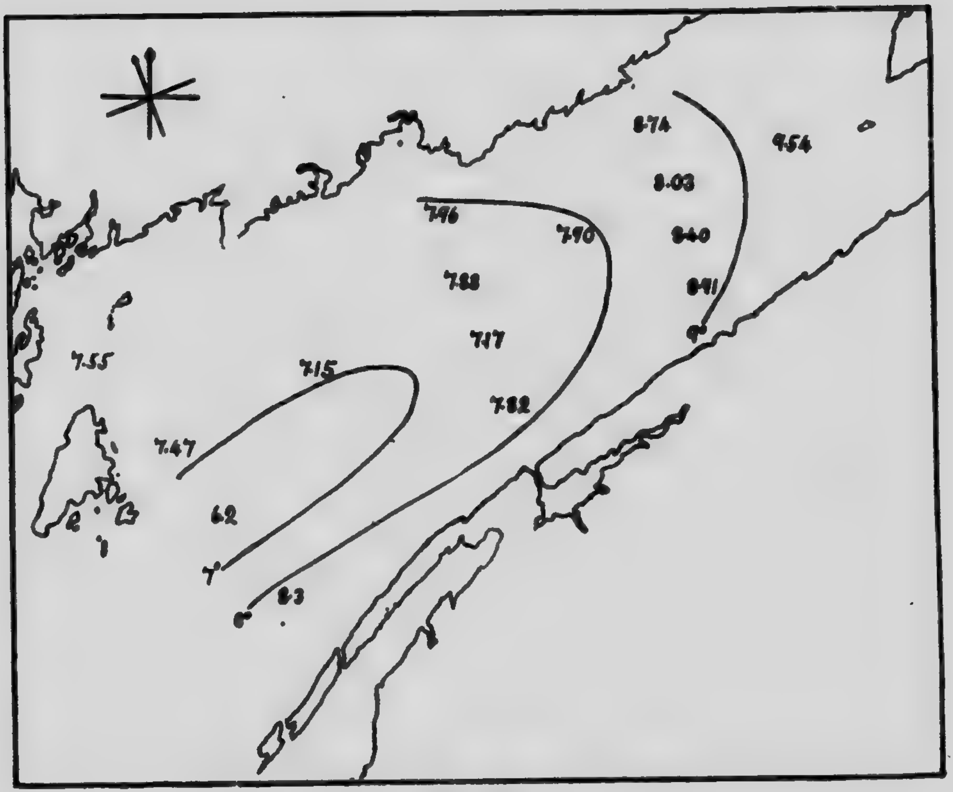


**Fig. 21.**

Figs. 21. The Bay of Fundy, showing temperatures of the water at a depth of 10 fathoms.

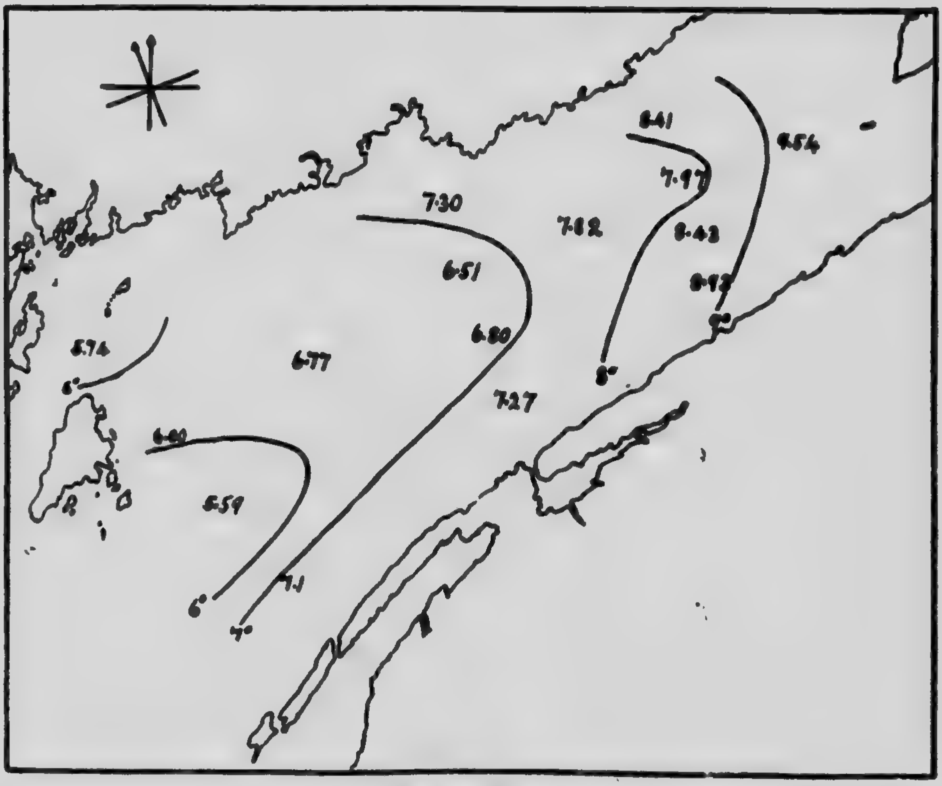


**Fig. 22.**

Figs. 22. The Bay of Fundy, showing temperatures of the water at a depth of 30 fathoms.

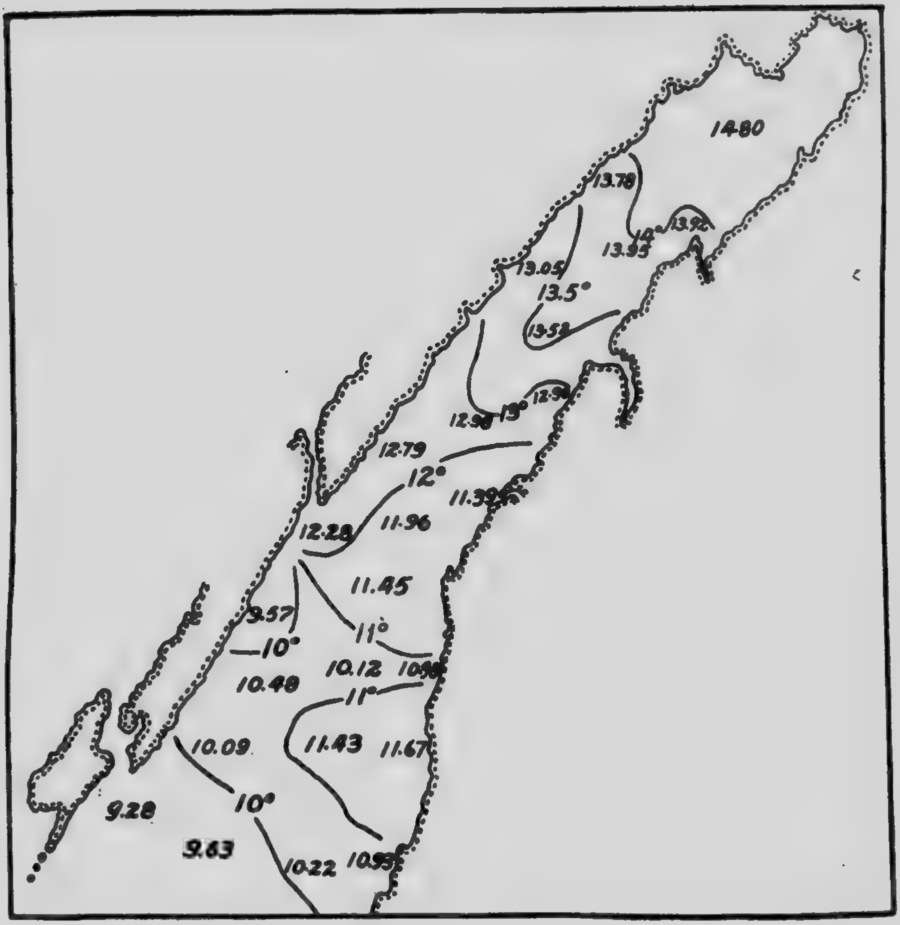
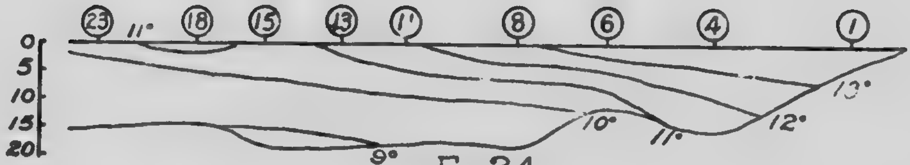


**Fig. 23.**

Figs. 23. St. Mary Bay, showing temperatures of the surface water.



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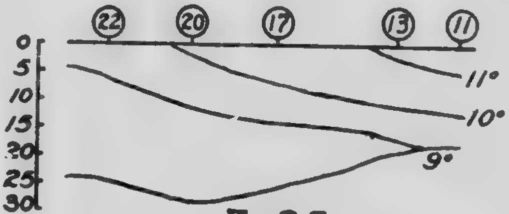
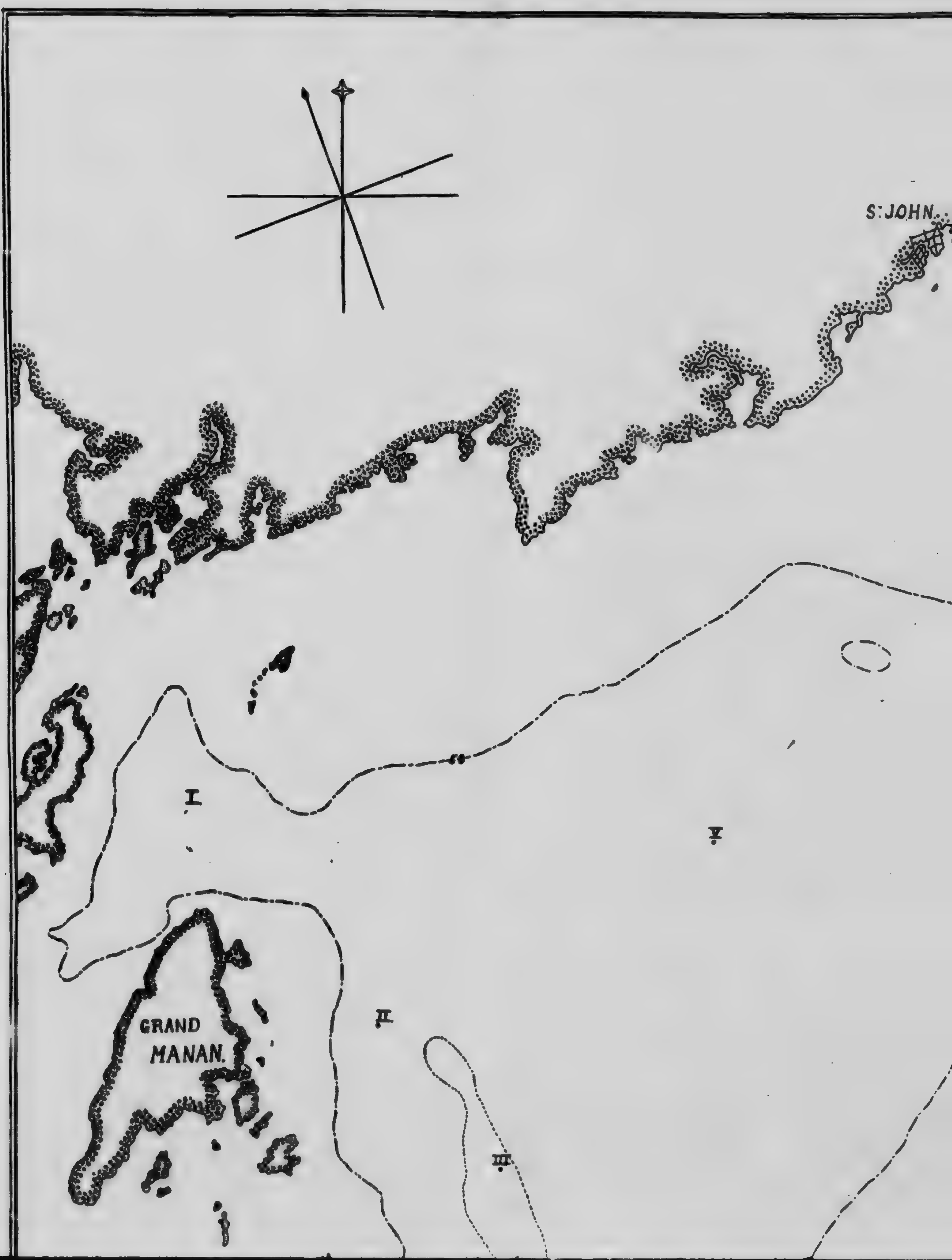


Fig. 25.

Figs. 24 & 25. Longitudinal isothermal profile of St. Mary Bay.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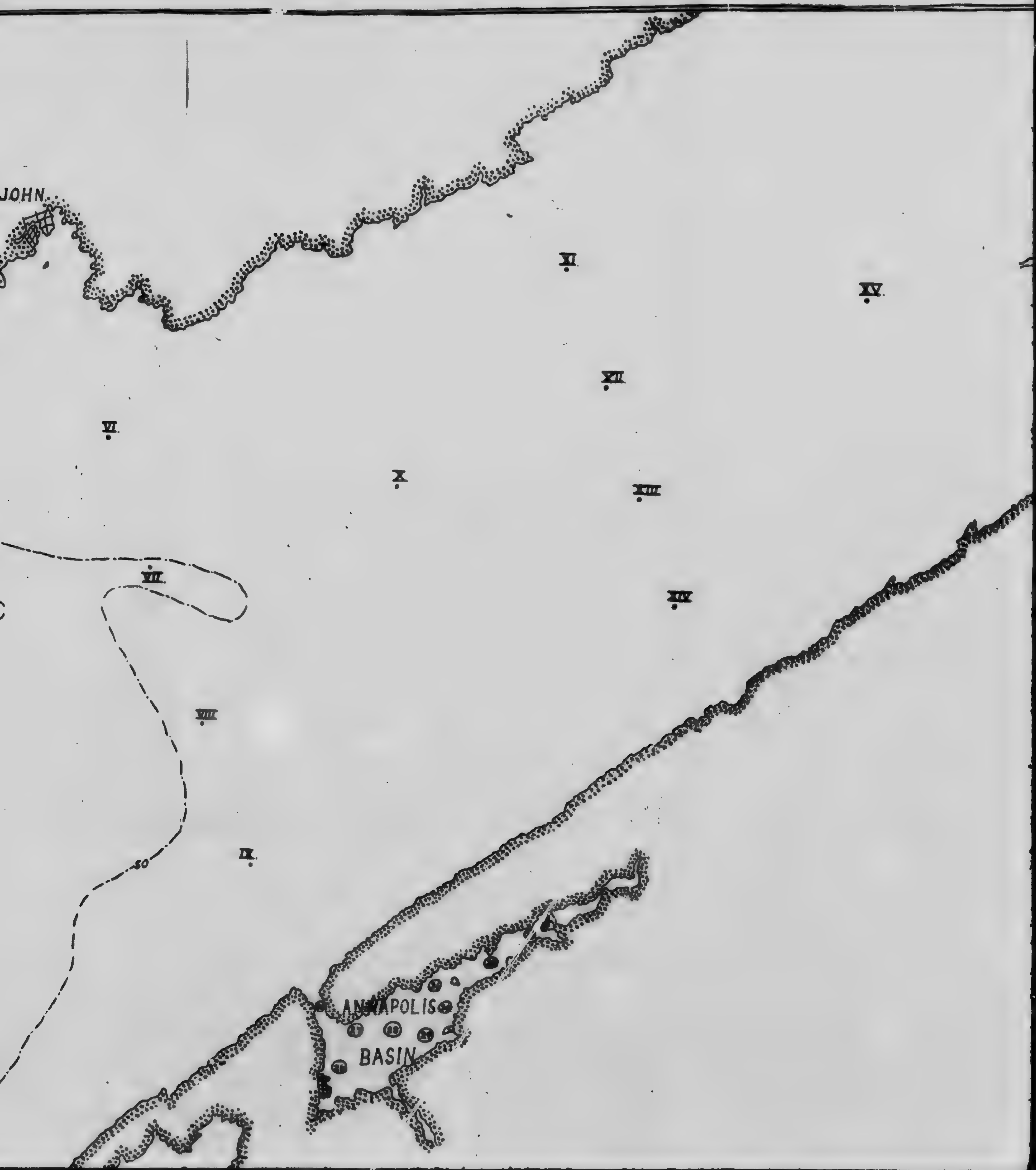
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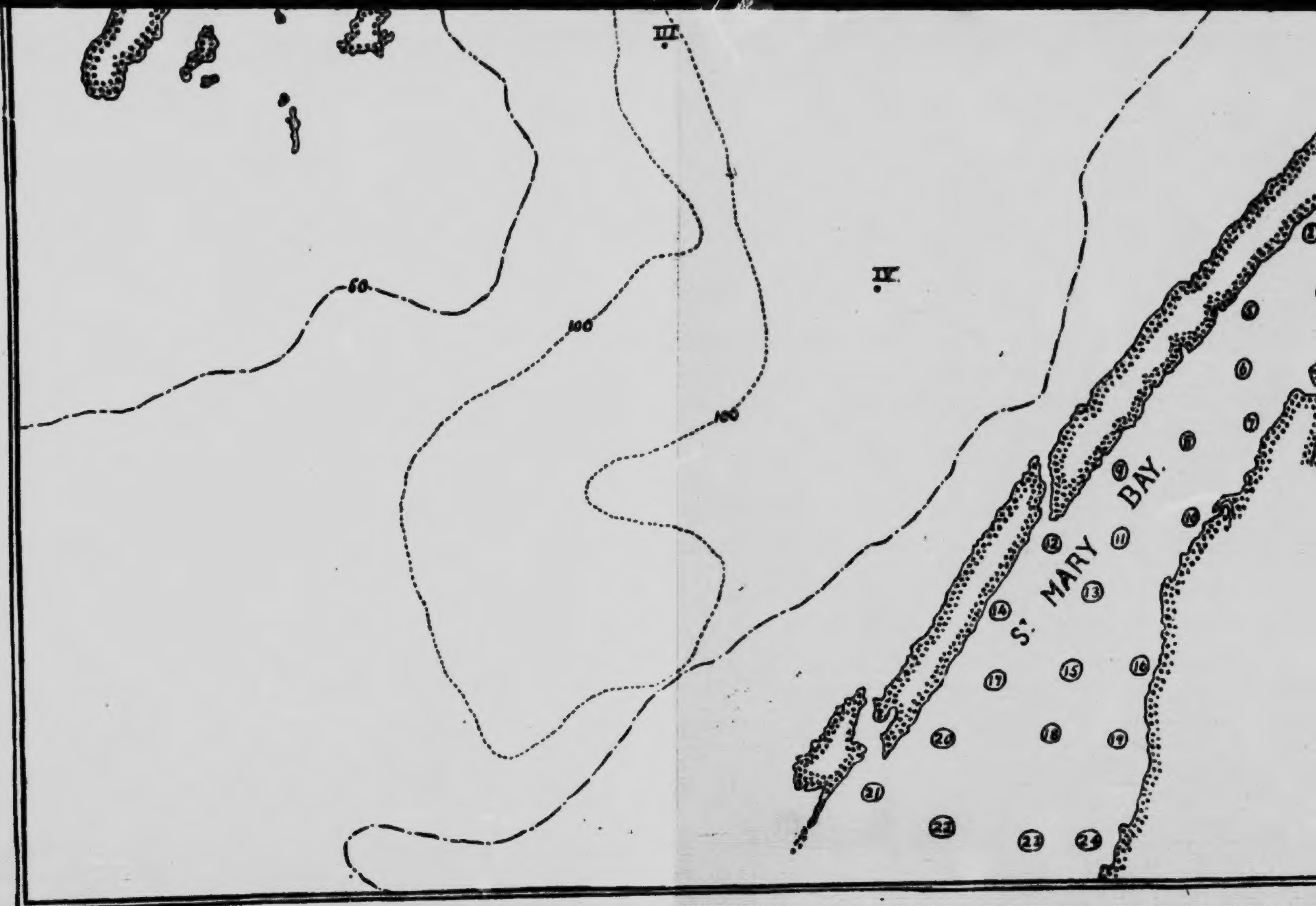
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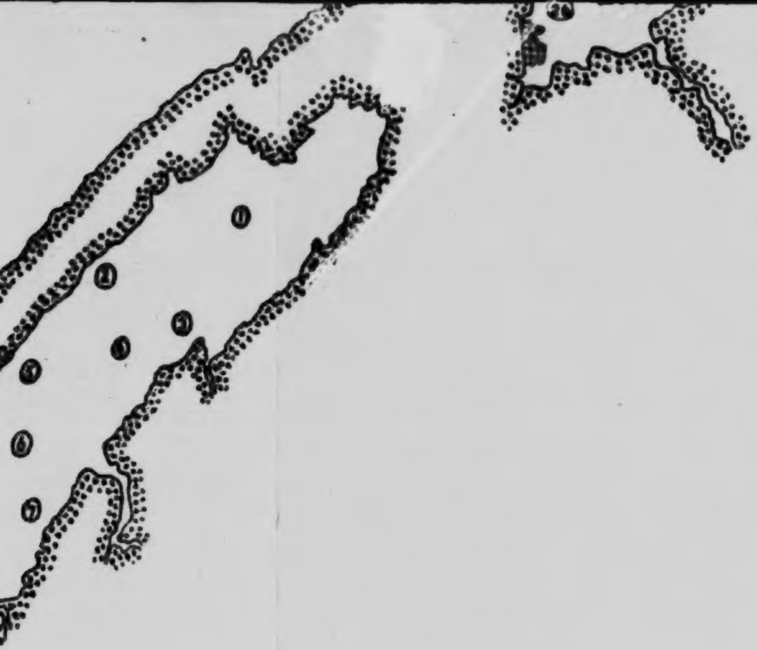

# BAY OF FUNDY

showing

HYDROGRAPHIC & DREDGING

STATIONS of 1915.

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showing

OGRAPHIC & DREDGING

STATIONS of 1915.